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ABSTRACT

From the standpoint of information network technology there is a necessary emphasis upon compatibility requirements which, in turn, will be met at least in part by various techniques of achieving convertibility --- between machine and machine, between man and machine, and between man and man. It may be hoped that improved compatibilities between machines and between men and machines will lead to more effective man-to-man communications. In general, the compatibility problems in network planning and implementation are those of interface and interchange. These problems are not new. If an information management system is defined as emphasizing not only listing or retrieval by category but also the explicit identification of the individual record (including information on its location and availability) and as providing individual record retrievability, then, again, the interfacing problems are not new. However, at least two major factors are new: (1) the formalization of information exchange networks and (2) the emergence of the teleprocessing technology, the "marriage" of computers and communications. (Other papers from this conference are available as LI 003360 - 003379 and LI 003381 through LI 003390) (Author/NH)

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COMPATIBILITY PROBLEMS OF NETWORK INTERFACING

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COMPATIBILITY PROBLEMS OF NETWORK INTERFACING*

INTRODUCTION

In the early 1960's, the National Bureau of Standards, with the support of the National Science Foundation, prepared and issued a special literature review on Cooperation, Compatibility, and Convertibility Among Information Systems[1/]. Of these "three C's", the greatest was and is still cooperation, which, as noted in another paper prepared for this Conference[2/], has had a long and healthy history in the library community.

From the standpoint of information network technology, however, there is a necessary emphasis upon compatibility requirements which, in turn, will be met at least in part by various techniques of achieving convertibility --- between machine and machine, between man and machine, and between man and man. It may be hoped that improved compatibilities between machines and between men and machines will lead to more effective man-to-man communications.

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* Contribution of the National Bureau of Standards, based upon a study of standardization, compatibility, and convertibility requirements in network planning, conducted for the Lister Hill National Center for Biomedical Communications.

1/ M.M. Henderson, et al., 1966.

2/ D. Weber, "History of Interlibrary Cooperation", 1970.

In general, the compatibility problems in network planning and implementation are precisely those of interface and interchange. If we take the long view, then certainly these problems are not new. If we define an information management system[3/] as emphasizing not only listing or retrieval by category but also the explicit identification of the individual record (including information on its location and availability) and as providing individual record retrievability, then, again, the interfacing problems are not new.

3/ By contrast to "management information systems" which are designed to provide managerial, accounting, and statistical data for a variety of policy, planning, auditing, billing, and evaluation purposes.

However, at least two major factors are new under the sun of the 1970's. These are, first, the formalization of information exchange networks[4/] and, secondly, the emergence of the teleprocessing technology, the "marriage"[5/] of computers and communications.

4/ "At many recent meetings, the topics of library networks and interlibrary cooperation have been treated as startingly new ideas, suddenly burst forth as glorious revelations to the library community. In fact, of course, we have had interlibrary cooperation and informal networks at least since the turn of the century --- ever since the beginning of the LC card service in 1901 (the sharing of bibliographic data), the development of the ALA Catalog Rules in 1908 (the standardization of bibliographic description), and the publication of the ALA interlibrary loan code in 1917 (the voluntary sharing of library resources). What is new today is the attempt to extend and carry forward these early concepts by placing them upon a sounder and more equitable financial basis, by creating formal organizational and contractual relationships between libraries, and by utilizing the latest technological developments to carry them out." P.J. Paulson, "Networks, Automation and Technical Services", 1969, p. 516.

"Such library of information networks would be a formalization of the cooperation that has existed for many years among libraries, in the form of interlibrary loans, union catalogs, cooperative cataloging, union lists of serials, etc. With the proliferation of tools, resources, and programs, such formalization and coordination is indeed necessary." S. Herner, "The Place of the Small Library in the National Network", 1966, p. 172.

5/ "Marriage of the computer to communications is a significant development. It means that the language of the computer can be exchanged over standard telephone lines, over teletype lines, through coaxial cables, via microwave radio broadcasting, and even by way of satellites. These same communication lines can be used to transmit line copy, pictures, or facsimile combinations of them both." J. Becker, "How Library Automation will Influence New Building Plans", 1969, p. 30.

THE STATE OF THE ART

The new technologies are literally forcing a new look at our problems of compatibility. At the same time, these technologies offer new opportunities, and new aids, for the solution of some of the problems. Among the obvious requirements for compatibility are questions of compliance with applicable standards; the development of mutually-acceptable conventions of description, documentation, access, and accounting, and the adoption of preferred common practices.

The compatibility problems at the many points and the many levels of interfacing are manifold, and many of them are unprecedented. In particular, the types of interface to be encountered in the teleprocessing situation present special problems, ranging from the technological (the possible use of adaptive modems) to the socio-political and the economic (differential tariffs for intrastate as versus interstate communications).

Nevertheless, the literature pertinent to compatibility requirements in network is surprisingly extensive and highly diversified. The 1966 study on cooperation, compatibility, and convertibility cited 600 references, and a bibliography of 463 references is included in a report to NLM. The topics range from standardization (including published standards as such) through communications (e.g., the FCC Inquiry on Computers and Communications) and descriptive cataloging (the MARC II format) to management control requirements (e.g., charging and pricing policies).

However, very little of this literature is directly addressed to compatibility problems in network interfacing. Notable exceptions of course include some of the available standards themselves (ASCII Code, MARC II, microfiche, and signaling speeds, in particular), the EDUNET studies[6/], the emphasis on the interface message processor (IMP) in the ARPA network[7/], Auerbach studies for the National Agricultural Library[8/], and the 1968 paper by Little and Mooers[9/], among others. In a few cases, the state of the practice in specific situations has been described --- for example, some of the solutions to incompatibility in the MEDLARS system for magnetic tape interchange.[10/]

Becker and Olsen, reviewing the 1967 literature, state that: "Much was written on the virtues of connecting smaller information networks to larger ones, but no blueprint is yet available that outlines how compatibility is to be achieved."[11/]

6/ G.W. Brown et al., EDUNET - Report of the Summer Study on Information Networks, 1967.

7/ C.S. Carr et al., "HOST-HOST Communication Protocol in the ARPA Network", 1970; L.G. Roberts and B.D. Wessler, "Computer Network Development to Achieve Resource Sharing", 1970.

8/ G. Cadwallader, et al., Format Compatibility and Conversion Among Bibliographic Data Bases, 1969; H.B. Landau, Research Study into the Effective Utilization of Machine-Readable Bibliographic Data Bases, 1969.

9/ J.L. Little and C.N. Mooers, "Standards for User Procedures and Data Formats in Automated Information Systems and Networks", 1968.

10/ C.J. Austin, MEDLARS 1963-1967, 1968.

11/ J. Becker and W.C. Olsen, "Information Networks", 1968, p. 318.

These authors emphasize the following problem areas:

- Critical questions of standardization
- Copyright requirements
- Privacy safeguards
- Costs and economic justifications
- Social acceptance
- Present or potential regulatory policies and practices
- International implications

In general, the problems of information are so new and so complex that a state-of-the-art assessment of compatibility requirements for interfacing is not yet possible. Nevertheless, compliance with established standards, rules, codes, conventions, and protocols for each and every interface situation in any real or prospective network is the first prerequisite for good management planning and effective management control. A second prerequisite is that of developing appropriate compromises (technological, managerial, and socio-political) in the design of network processes, procedures --- and, most importantly, policies. The third and most significant prerequisite is that of adequate responsiveness to the challenges, (both implicit and explicit) in the "marriage" of computers and communication systems to the development of truly efficacious "networks for knowledge."

STANDARDIZATION

The first compatibility requirement to be considered is that of compliance with current standards. These are mostly of a voluntary nature, whether promulgated at the national level (e.g., the American National Standards Institute, ANSI[12/]) or the international (the Internations Standards Organization, ISO), by professional societies such as the American Library Association, or by special interest organizations such as the Council on Scientific and Technical Information, COSATI. However, the emergence of the Federal Information Processing Standards (FIPS) program is especially to be noted.

It is to be emphasized that "a 'standard' is a mutually agreed upon method for referring to or describing the essential aspects of some object or some action of common interest"[13/] and that a standard is an agreement "by which the design, performance, and other characteristics of products, processes, services and systems are described"[14/], rather than an arbitrary rule or

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12/ Formerly the United States of America Standards Institute and, before that, the American Standards Association.

13/ C.N. Mooers, Standards for User Procedures and Data Formats in Automated Information Systems and Networks, Part 1, 1967, p. 1.

14/ G.J. Rothwell, "The Performance Concept: A Basis for Standards Development", 1969, p. 1.

constraint. It is to be recognized further that standardization of the many and varied types of data elements, formats, languages, and procedures that already exist is generally impossible, and probably undesirable as well, so that current standardization efforts emphasize description, interchange, and the problems of effective interfacing.

In general, standards are voluntary standards, arrived at cooperatively. For the Federal community, however, mandatory information processing standards are authorized under the Brooks Bill (P.L. 89-306) of 1966. Some ten or more Federal Information Processing Standards have been issued as of the date of this Conference. The FIPS are binding, with the exception of the meeting of appropriate waiver requirements, upon all Federal Agencies and, importantly, upon contractors and grantees supported by Federal-Agency funds. Thus, for information-management-networks that will have U.S. Government participation, or Federally sponsored participants, supported in whole or in part by such funds, these standardization requirements must be faced.

Most of the FIPS that have been promulgated to date have to do with standard representations of data elements such as calendar date, counties of the States of the United States, and the like. Three, however, directly affect network interfacing requirements. These three involve the Code for Information Interchange (ASCII) and its representation on perforated tapes and on magnetic tapes. These FIPS adopt the corresponding ANSI voluntary standards (X3.4-1967, X3.4-1968, X3.6-1965, and X3.22-1967).

Although these FIPS requirements are binding only upon Federal Agencies and upon-Federally-supported potential contributors to and participants in an information-management-network, it is to be stressed particularly that the standards are directed specifically to interface and information interchange --- leaving considerable latitude for local procedures and practices to continue as they now are, or to be adapted as necessary. For example: "This standard will be prescribed for the interchange of formatted machine sensible coded data between and among agencies. Use within agency systems is encouraged when such use contributes to operational benefits, efficiency or economy."

Additional FIPS currently under development and likely to affect compatibility requirements at network interfaces include the following (the corresponding American National Standards designation are given as appropriate):

- Signaling speeds for data transmission (X3.1-1962)
- Parallel signaling speeds for data transmission (X3.13-1966)
- Specifications for general purpose paper cards for information processing (X3.11-1966)
- Time sharing and remote console considerations
- Hardware interfaces
- Recorded magnetic tape for information interchange (X3.14-1969)
- Bit sequencing of the AN Standard Code for Information Interchange in serial-by-bit data transmission (X3.15-1966)

Signal quality at interface between data processing terminal equipment and synchronous data communication equipment for serial data transmission (X3.24-1966)

It will be noted that with the sole exception of the area of time sharing and remote consoles, the standardization considerations are strictly directed to the interfaces between machine and machine. Similar emphasis is to be found in the work of many of the Sectional Committees of ANSI: X3, Computers and Information Processing; X4, Office Machines; PH5, Photocopying, and PH7, Photographic Audio-Visual Standards.

Both man-machine and man-man interfaces are involved, however, in the work of ANSI's Sectional Committee Z39, Library Work and Documentation and Related Publishing Practices. Current voluntary standards developed by this Committee are:

- Z39.1-1967, Periodicals (Corresponds to the international standard ISO R8)
- Z39.4-1968, Basic Criteria for Indexes
- Z39.5-1963, Periodical Title Abbreviations
- Z39.6-1965, Specifications for Trade Catalogs
- Z39.7-1968, Compiling Library Statistics
- Z39.8-1968, Compiling Book Statistics

Most important from the standpoint of compatibility requirements in information center and library networks, however, is the current work on the adoption as a voluntary national standard of the format for bibliographic information interchange on magnetic tape. The draft of the proposed American National Standard contains as an appendix: "Preliminary Guidelines for the Library of Congress, National Library of Medicine, and National Agricultural Library Implementation of the Proposed American Standard for a Format for Bibliographic Information Interchange on Magnetic Tape as Applied to Records Representing Monographic Materials in Textual Printed Form (Books)." This, of course is the implementation of the MARC (Machine-Readable Cataloging) II format.

The following points are to be noted:

- If adopted, the proposed AN standard will undoubtedly be considered for adoption as a Federal Information Processing Standard and thus would become mandatory for Federal components of an information network.
- By mutual agreement, the proposed AN standard, in the MARC II implementation, is being followed by the three National Libraries in exchange of monograph information amongst themselves.
- The MARC II implementation is in use by the Library of Congress for the weekly distribution service of LC cataloging on magnetic tapes. The RECON (Retrospective Conversion) Pilot Project provides for the conversion of retrospective cataloging records to this format.

- A second implementation of the proposed standard has been developed for the technical report literature by Panel 1, COSATI.
- "This standard defines a format which is intended for the interchange of bibliographic records on magnetic tape. It has not been designed as a record format for retention within the files of any specific organization. Nor has it been the intend of the subcommittee to define the content of individual records. Rather it has attempted to describe a generalized structure which can be used to transmit between systems, records describing all forms of material capable of bibliographic descriptions as well as related records such as authority records for authors and subject headings."15/ Thus, the adoption of this standard need not require extensive modification of in-house programs and procedures, provided that general conversion programs (from and to the standard format) can be developed and provided that adequate documentation of deviations or specialized usages are made available for the use of others.
- The proposed standard is highly flexible and it is character-oriented and therefore machine or program-language independent.

15/ American National Standards Institute, Draft, Z39.2-1968.

The four major intended characteristics of the format are, in the words of its principal developer, as follows:

> "1. It establishes the means by which bibliographic information may be transmitted between libraries.
>
> "2. It describes the rigorous rules by which bibliographic information, available in human-readable form, may be converted to machine-readable form.
>
> "3. It suggests that if the same format is used for the exchange of information by all libraries, programs and procedures may be exchanged and automation costs reduced.
>
> "4. It follows the ... [ANSI] Code for Information Interchange (ASCII), the Standard for Recorded Magnetic Tape for Information Interchange, and the proposed Standard for Magnetic Tape Labels and File Structure."16/

A wide variety of other standards have been developed at various levels such as the international (UNISIST, the Joint ICSO-Unesco feasibility study looking toward a world-wide system for the handling of scientific information; various standards of the International Standards Organization including ISO R9-1955, International System for the Transliteration of Cyrillic Characters; the International Electrotechnical Commission; the NATO Automated Data Handling Working Party and the F.I.D., for example)

16/ H.D. Avram, "Using Computer Technology-Frustrations Abound", 1969, p. 43.

or the institutional (The Council on Library Resources, The American Library Association, the National Microfilm Association, COSATI, and CODASYL, the Conference on Data System Languages, among many others).

In general, compliance with standards as appropriate to an information network, where "more than two participants are engaged in a common pattern of information exchange through communications for some functional purpose"[17/], poses a wide variety of compatibility requirements; on the other hand, compliance with standards offers considerable promise for the resolution of interfacing problems.

17/ J. Becker and W.C. Olsen, "Information Networks", 1968, p. 289.

MACHINE-MACHINE COMPATIBILITY PROBLEMS

From a technological standpoint, the machine-machine type of interface is, of course, the most tractable. There are, equally obviously, many severe compatibility problems with respect to communication links, the communication systems as such, data access arrangements, buffering requirements, internal processing, programming languages, multiprocessing, multiplexing, physical materials and media. The broad areas of requirements for compatibility or convertibility between machines involve:

- Data transmission, with emphasis upon information interchange, but also including major considerations of differential speeds and costs
- Input/output equipment
- Reprography, specifically including microform technologies
- Other information storage equipments and media, including magnetic tapes, magnetic disks, and video tapes
- Machine interaction, including problems of scheduling and routing, resources allocation and reallocation, queue management, programming languages and program documentation, and, especially, linkages between processors of different types.

Considering the terminology "through communications" as essential in the Becker and Olsen definition of information networks given above, we begin with the data transmission area. Compatibility problems in this area arise with respect to both common carrier and non-common-carrier services and practices, with respect to reformatting and transformation requirements, and with respect to interface message processing and network buffering, among other factors.

Compatibility problems are likely to arise in network interfacing with regard to such communication questions as the following:

- What facilities and services (such as the public switched network, leased lines, closed circuit TV, facsimile transmission, microwave communication links, satellite services) are available at <u>each</u> node of the network? For example, to what extent could present or expanded educational TV networks be included in the system?
- What are the applicable tariffs and regulatory provisions for each data link or communication service between nodes and what are the comparative costs, performance factors, and reliabilities for each type of link or service for each connection requirement?
- What stand-by and emergency links and services are required? To the extent required, will they be freely available or must they be planned, and paid for, in advance of actual use?

- What are the switching facilities and requirements at local nodes, for clusters of nodes, and throughout the network?
- What differential transmission rates, signaling speeds, line conditioning provisions, interface devices, and similar factors are likely to be involved?

From the standpoint of many of these technical considerations it is to be emphasized that: "The important characteristics of data transmission are: the speed of transmission, the transmission method used (whether synchronous or asynchronous), the character coding, the order of transmission of bits for each character, and the usage of control characters and procedures. Conditions now exist that point to a need for uniform standards:

- ". The increasing proliferation of data transmission equipment and need for compatibility.
- ". The tendency of the Federal Government towards a unified set of data processing standards.
- ". The projected future growth of EDP in ... [national systems] and the need to integrate with other systems, local or statewide."18/

It is to be noted particularly that compatibility problems are at the heart of the "foreign attachment" controversies. First came the significant FCC decision reversing the Bell Company's previous arbitrary exclusion of customer-provided interface

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18/ M.S. Colah and R.W. Strunk, Civil Defense Communication Studies: Data Transmission Standards, 1969, p. v.

equipment from being interconnected with the public network[19/] and requiring that the burden of proof of incompatibility should rest with the carrier rather than with the client. More recently there have been questions of the compatibility or lack of compatibility of intrastate and interstate tariffs, especially for "information service access lines."[20/]

The most recent development in the foreign attachments area is the establishment of a National Academy of Sciences Panel to hold hearings, to arrange informal conferences for interested parties, and to prepare recommendations for FCC decision. Among the issues to be considered are problems of network control signal equipment, interface requirements, transmission quality, and protection mechanisms.

19/ The basic decision by the FCC on June 26, 1968 was that the prohibitory "tariffs in question 'are, and have since their inception been, unreasonable, unlawful, and unreasonably discriminatory' under the Communications Act. What the FCC sought to do in the Carterfone decision was to follow the standard set forth by the Court of Appeals in the Hush-A-Phone case. That is, to allow a telephone user to use his service in ways that are privately beneficial without being publicly detrimental." K.A. Cox, "Carterfone and the Computer Utility", 1969, p. 3.

20/ "Basically the dispute is whether data transmitted to or from a terminal in one state, through a customer-supplied multiplexer in the same state, to a computer in another state is partly or completely interstate communications. The carriers insist the terminal-multiplexer link is intrastate; the service bureaus insist the whole communications path should be subject to interstate tariffs." Datamation 16:165 (Jan. 1970).

With respect to tariffs and regulatory provisions affecting compatibility problems in information network interfacing generally, it is to be noted that "the success of the planning of the Three National Libraries in the area of networking depends upon the careful revision of the Federal regulatory policy."[21/] Further, the FCC Inquiry on the Interdependence of Computer and Communication Services and Facilities, raised the following questions: "(1) the extent of regulation if any, of the computer industry, including questions as to whether carrier and computer entities should provide service in each other's area; (2) the adequacy of carrier services and facilities, including possible new bases for charges; and (3) the protection of privacy and security of data, while stored in computer memory and during transmission over common carrier facilities."[22/]

Among the responses to the Inquiry, as analyzed by a study team at Stanford Research Institute, some of those that are pertinent to compatibility requirements for information networks are as follows:

21/ L.G. Livingston, "Computer Utilities and the Three National Libraries", 1969, p. 2.

22/ K.A. Cox, "Carterfone and the Computer Utility", 1969, p. 4.

- "A need for data on error performance and circuit characteristics with respect to amplitude and delay ... A need for standards with respect to circuit reliability and transmission quality ... A need for reduction in the variability of transmission performance in the public switched networks..."[23/]
- "Interconnection of users' computer interface equipment, communications links and systems with carriers' systems should be permitted, subject only to well-defined technical standards to protect the integrity of carriers' systems."[24/]
- "Data on system error performance should be published so that the data processing industry can develop appropriate error protection systems."[25/]
- "The variability of data transmission performance on the public switched network should be reduced."[26/]
- "The variability of intrastate tariffs and services among the states should be reduced."[27/]

23/ D.A. Dunn, Policy Issues Presented by the Interdependence of Computer and Communications Services, 1969, p. 47.

24/ L.I. Krause, Analysis of Policy Issues in the Responses to the FCC Computer Inquiry, 1969, p. 53.

25/ Ibid.

26/ Ibid.

27/ Ibid.

Compatibility requirements for the communications system or systems for an information network considered as a whole are first directed to questions of organizational structure: centralized, partially centralized, or distributed. In the fully centralized case, compatibility problems of interfacing are usually amenable to relatively straightforward resolution.

A partially centralized network is exemplified by a system of interconnected regional centers, each serving a number of separate nodes. The partially centralized system is typically a multipoint network, raising serious questions of optimizing the many possible configurations.[28/] Regional centralization techniques may extend down to the "cluster" concept.[29/]

28/ L.R. Esau and K.C. Williams, "On Teleprocessing System Design", 1966, p. 144.

29/ "A number of new developments are based on the need for serving clustered environments. A cluster is defined as a geographic area of about three miles in diameter. The basic concept is that within a cluster of stations and computers, it is possible to provide communication capabilities at low cost. Further, it is possible to provide communication paths between clusters ... and still maintain economies within each cluster." R.L. Simms, Jr., "Trends in Computer/Communication Systems", 1968, p. 23.

The organizational principle of distribution may affect either the physical structure of the network or the routing of message traffic or both. Thus, "by a distributed implementation of an information service system we mean that the data processing activity is carried out by several or many installations... The data base is now distributed among the installations making up the information network... The distributed information network should offer considerable advantage in reducing the cost of terminal communications by permitting installations to be located near concentrations of terminals."30/ It is further claimed that: "The concept of distributed data bases and distributed access to the data is one of the most powerful and useful applications of the [ARPA] network."31/

For highly distributed systems the compatibility problems obviously include the questions of the types of processing to be performed at stations at each given level and of the accounting and reporting to be required at successively higher levels.

30/ J.B. Dennis, "A Position Paper on Computing", 1968, p. 373.

31/ L.G. Roberts and B.D. Wessler, "Computer Network Development to Achieve Resource Sharing", 1970, p. 548.

Other compatibility problems in linking computers and communications systems in an information network involve questions of circuit-switching as against message switching; synchronous and parallel modes of transmission; simplex, half-duplex, or full-duplex lines and data sets. It may be assumed that an information network for the handling of recorded knowledge will require both analog (voice, facsimile) and digital data transmission.

A proper balancing of cost, speed, and distance considerations in the choice of specific communication facilities (narrow-band, voice-band, broad-band, and other services) must be achieved. Nevertheless, "it must be noted that not all of the various kinds of channels and methods of transmission are available to the data customer on an off-the-shelf basis. Not all bandwidths are available in every part of the country."[32/]

Since the information network will undoubtedly involve participation and cooperation by individuals, systems and institutions in other countries, compatibility difficulties with respect to international communications standards and procedures must be considered. Thus: "To change analog signals into digital

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32/ H.J. McMains and G.L. Bromleigh, Jr., "Telephony and the Library", 1969, p. 4.

form, European Countries, for example, follow a different coding law than the U.S. and Japan. As things stand now, the prospects for agreement have to be rated as poor. Moreover, the English handle 24 voice channels on a single line as do the Americans and Japanese, but the Europeans bundle 30 together. And some countries code analog samples into seven binary digits, others into eight."[33/]

Compatibility problems with respect to communications format occur at at least three levels: that of character set (e.g., ASCII; that of composition format, "concerned with the arrangement of the data and the space allotted to them within the message"[34/], and that of physical format involving the physical structure of the information signals.

In particular: "Wherever there is an interface between equipments collecting information and those transmitting it, between two types of transmitting equipment, or among transmitting equipments and receptors, a facet of the formatting problem occurs. The formats chosen have a strong effect upon the design of interfacing equipments and therefore upon the capabilities of

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33/ W. Bucci, "PCM: A Global Scramble for Systems Compatibility", 1969, p. 94.

34/ D.C. Friedman, Global Information Handling System - Aspects of the Formatting Problems, 1963, p. 3.

the information handling system, and the delays incurred in passing through it. Thus, the solutions of ... format problems will have far from negligible effects upon the economics of providing an information handling system, its capabilities, and its response times."35/

Compatibility or convertibility at various communication interfaces (originators, distributors, receivers) will be required for some or all of the following:

- Conversions, as to and from analog and digital or serial and parallel
- Message blocking and message segmentation, particularly in terms of standardized packets
- Message elements, including headings, ID information, information separators, function effectors (e.g., control characters)
- Escape coding and privacy transformations
- Error detection and correction requirements, including procedures for the recovery of missing or garbled messages.

35/ Ibid, p. 1.

The control procedures as such require standardization or at least established rules or conventions governing network-wide usage. In a proposed AN Standard for data control procedures using ASCII for information interchange, a number of categories of control procedures are defined. Functions presently covered include polling of the different stations, identification, contention, selection, framing of messages and transmission blocks, replies to messages or blocks, invalid or no reply situations, termination, and mandatory disconnection. Also to be considered are preemption, interrupt, and abort functions; handling of "transparent mode" messages, and system timing and synchronization requirements.

Convertibility as a solution to reformatting, retransmission, and error checking problems may be achieved both by the adoption of appropriate protocols and by combined software-hardware techniques, as in interface message processors. Some examples of protocol considerations are as follows:

- "Communications protocol here refers to the uniform agreed-upon manner of exchanging messages... This includes data link control, acknowledgments and error recovery procedures. It may also include message buffering and routing techniques... A single standard procedure may not be practical because of varying needs of different systems and discrepancies in their hardware/software characteristics. Operation could be synchronous or asynchronous, full duplex or half duplex, point-to-point or multipoint, centralized or decentralized, and over private line, switched network,

or a general network environment employing store-and-forward routing techniques. In many of the above cases, the protocol needs would differ, and hence the procedures adopted would vary."[36/]

. "It is proposed that there would be an agreed-upon standard control signal which will cause any cooperating automated system to go into the standard mode. This stratagem will allow local parochial control methods to live side-by-side in more or less harmony with whatever standard control methods that may be established. Each automated system can then be receptive to the basic command 'go into standard mode' with a minimal burden upon the rest of its operation."[37/]

. "It would appear that it should be an EDUCOM responsibility to standardize on-line communications up to the interface with the members, and that the members should have the responsibility of meeting these standards through acceptance of them or through local translators into alternative local systems."[38/]

36/ A.K. Bhushan and R.H. Stotz, "Procedures and Standards for Inter-Computer Communications", 1968, p. 102.

37/ C.N. Mooers, Standards for User Procedures and Data Formats in Automated Information Systems and Networks, Part I, 1967, pp. 9-10.

38/ G.W. Brown et al. Eds., EDUNET - Report of the Summer Study on Information Networks, 1967, pp. 172-173.

- "... The establishment by the network controlling body of universal standards to which all nodes must conform. Thus a message arriving at or leaving any node would appear identical, requiring two (or more) routines (unless the local standard was the universal standard) at each node to convert between the standard local. There would probably have to be more than one standard (e.g., ASCII for messages, a standard for boundary conditions to routines, and a standard for requesting of execution and storage facilities on other nodes)."[39/]

- "... The establishment of a message protocol, by which we mean a uniform agreed-upon manner of exchanging messages between two computers in the network."[40/]

- "For a large scale party-line (multidrop) network, provisions should be made to maintain a network discipline that will ensure increased system efficiency as well as dependable service."[41/]

39/ Ibid, p. 251.

40/ T. Marill and L.G. Roberts, "Toward a Cooperative Network of Time-Shared Computers", 1966, p. 428.

41/ H-N. Liu and D.W. Holmes, Teleprocessing Systems Software for a Large Corporate Information System, 1970, p. 2.

Other compatibility problems related to protocols and network discipline include the following:

- Compatible entry and access controls must be provided, including the identification and authentication of authorized terminals, authorized users, and authorized destinees.
- Buffering requirements at sender, relay, receiver, and processors stations. For example, at receiver terminals or other sinks, the necessary refresh-rate controls, reformatting capabilities, and code conversion facilities must be considered.
- Routing requirements must also be considered, including types of routing, addressing schemes, and provisions for traffic control.

Typically, such compatibility requirements demand the use of some degree of interface message processing. For example, differential signaling speeds and rates of information transfer usually require the use of speed-change mechanisms.

Solution of compatibility problems for network interface buffering will generally provide:

- Intermediary message processing capabilities (in particular, the transliteration or transformation of encodings, or formats, or modes of interchange such as analog/digital, or rates of data transfer) to meet specific requirements of immediate interchange, retransmission, or local use

- Retransmission without substantive change other than, for example, signal amplification or error correction to one or more next-addresses
- Determination of best or next-best routings under normal, overload, and emergency-priority conditions
- Collection and recording of management accounting and control information
- Substantive modifications to the contents of messages or files
- Management of feedback information.

Specific buffering requirements arise in the clustering of local stations or consoles and to display processing at remote terminals. Further, "there is a growing awareness that display buffers should, in fact, be small general purpose computers, which opens up a whole new spectrum of possibilities in properly assigning tasks witnin the overall system."42/

Logical design considerations with respect to terminal compatibility in network interfacing relate to character sets and information transfer rates, to control functions and control codes and keys, and to data and format convertibility. Engineering design considerations range from questions of ambient lighting and design of keyboards (including the use of overlays which may be of particular interest in terms of specialized local usage) to those of interfacing with the communication system, with local

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42/ J.E. Ward, "Systems Engineering Problems in Computer-Driven CRT Displays", 1967, p. 49.

processor facilities, and with other processors.

It is to be noted that different terminals for output and display that are available commercially are not usually compatible with one another. Often a CRT display terminal is not compatible with teletype transmission requirements, either, yet many potential patrons of the network services will be dependent upon teletype rather than more sophisticated and more costly output and display equipment.

The spectrum of terminal equipment to be expected at network interfaces will include:

- Keyboard entry devices, single-stroke and multiple-stroke
- Keyboard devices with subsequent conversion by means of optical character recognition or stenotype decoding
- Hand-entry devices such as light pens
- Display consoles for alphanumeric and graphic information, with or without hard copy or microform print-out options
- Printers, both on-line and off-line, with or without typographic quality capabilities
- Direct computer-output-to-microform (COM)

In the case of graphic display equipment, some of the questions of compatibility concern are the X-Y plotting capabilities; the image-manipulation facilities (including rotation, translation, change of scale, blow-ups, contrast enhancement, perspective projection, shading), and the availability of hard-copy options, among other factors.

In the case of microforms, there are questions of the number of page images to be placed on a microfiche or an ultrafiche, of reduction ratios, and of reproducibility (i.e., how many copy-generations can be produced with adequate readability and contrast). For ultrafiche, in particular, the technological factors requiring standardization or compatibility considerations include the effects of size, contrast, handling of media, and resolution, on the control of access and retrieval and on the usefulness of the microcopy, especially at very high reduction ratios.

In general, mixtures of output modalities will pose serious compatibility problems in planning for network interfacing. Mayeda points out that, with the exception of some military applications, most information processing systems have been "single path", but that the newly emerging network requirements will demand "the mixing of normally incompatible media into one information transfer system."43/

43/ T. Mayeda, "Methodology in Presentation --- A New Objective: The Multi-Media Network", 1967, p. 4.

MAN-MACHINE COMPATIBILITY PROBLEMS

While the general compatibility problems between and amongst machines are reasonably tractable and are beginning to yield both to hardware and software developments for more effective convertibility in interfacing and also to standardization efforts, the interfaces between man and machine present both more fundamental and also more difficult challenges. The man-machine compatibility problems occur at three major levels:

- The individual and the specific machine component of the network
- The individual and the network system
- The community or communities of users and the system

Consideration of the compatibility problems of man-machine interaction should obviously begin (and always return to) the ultimate interface --- that between the user and the network services provided to him. Thus there is first the thorny question of user requirements. Shall we ever be able to assess objectively what our users (or patrons, or clients) really want and what they really need? (A basic difficulty in terms of resolving this problem is, of course, that "wanting" and "needing" often have no correlationship). From a technological point-of-view, we can obviously leave some of the more severe problems actually involved at the user interface to others (including users themselves).

The compatibility problems of network users begin first, of course, with the problems of accessibility --- from physical access to ease of use of system facilities and resources and ease of learning to use them.

Who requires direct physical access, when, where, and for what purposes to terminals, microform viewers, hard copy of books, documents, and records? Is the computer room at a major processing node accessible only to "authorized personnel"? How often are requested items off the shelves? What happens when all the lines are busy or a massive power failure occurs?

Next we may consider the user's physical interaction. Here the areas of compatibility involve on the one hand his interests, habits, attitudes, and expectancies, and, on the other hand, the physiological constraints such as flicker rate acceptability, reaction time, reading time. "How clumsy are light pens or pointers to use? Are they heavy or difficult to aim? Should light-pen inputs be displayed a little to the left or to the right of the actual light-pen location so that the active part of the input is not blocked from view by the moving light-pen itself? ... For graphic input and display should the input surface be flat, upright, or slanted?"43/

43/ M.E. Stevens, Research and Development in the Computer and Information Sciences, Vol. 3, 1970, p. 10.

What are the compatibility problems for the individual user in actual use of various types of terminals at various nodes of the teleprocessing network? Standard mode of access and use procedures are required to tackle such problems as programmable format control, switching from one character set to another, and a minimum set of logical control functions, mutually agreed-upon, which will in turn influence keyboard layouts. The user needs to know whether he is actually connected and how he is to query or otherwise use the system.

Motivational factors in man-machine compatibility involve the acceptability of the equipment itself[44/] and the acceptability of system performance including quality and legibility of outputs and displays and, particularly, speed of response.

Scherr has emphasized that "the response time of the system to a line of input from the user is an important parameter of a time-shared system. In fact it is one of the few, well-defined, measurable performance parameters available. This response time determines the basic rate at which the user can operate."[45/]

44/ "All employees from the factory worker through the clerk to the busy executive ... all have one point in common and that is that they will resist any amount of forcing them to adapt to a terminal. As such, the terminal must fit their environment, their mentalities, and if possible, become a part of their work station." (D.J. Dantine, "Communications Needs of the User for Management Information Systems", 1966, p. 406).

45/ A.L. Scherr, An Analysis of Time-Shared Computer Systems, 1965, p. 19.

Further a major distinction must be made between actually adequate and apparently adequate response times.46/

Finally, with respect to individual interaction with system components and subsystems, there are problems of the languages. "It has been estimated that the number of time-sharing installations is roughly equal to the number of languages offered among them."47/

At the level of individual interaction with the network as a whole, it is necessary to know, for each and every contributing node:

- Precise and accurate identification of its capabilities
- Precise and complete descriptions of the nature, format, scope, etc., of its holdings and other resources
- Full and complete documentation of procedures, programs, etc., as necessary for interactive use

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46/ "The apparent response time is a subjective evaluation of system performance made by a console operator in a man-machine system. Extensive human-factors tests are required to ensure that an acceptable real response time is, in fact, an acceptable apparent response time." (J.D. Aron, "Real-Time Systems in Perspective", 1967, p. 53).

47/ T. Marill and L.G. Roberts, "Toward a Cooperative Network of Time-Shared Computers", 1966, p. 426. Further: "The handling of displays in a time-sharing system is usually built right into the time-sharing monitor. Unfortunately, every monitor handles displays differently, with the result that each computer in the network must be programmed to understand the display languages of the others." (Ibid, p. 429).

- Specifications of applicable local arrangements, protocols, and requirements

It is necessary for the user to comply with system protocols, information interchange requirements, and management and control policies (including priorities, resource allocation, pricing, accounting, audit trail, and performance evaluation requirements). Requirements for the identification and authentication of legitimate users and legitimate usages of network resources are obvious.

Some specific compatibility questions are as follows:

- How do we guarantee authorized, but only authorized, access to privileged files and privileged information?
- How do we resolve priority and scheduling conflicts?
- How do we handle abuses or misuses, inadvertent or otherwise, of network resources and services?

It is necessary for the network management to know who the users are, to gather usage statistics, to monitor user performance, and to provide training and re-training facilities as required. There is apparently an appalling dearth of systematic, empirical

data with respect to user effectiveness.[48/]

- How is user performance to be monitored and appraised?
- What are the initial training requirements? (The "riding-circuit" procedures of the North Carolina Educational Computing Service may be of interest here.)[49/]
- What retraining facilities could be made available to member nodes where user inefficiencies can be observed?

Man-machine compatibility requirements at the level of community interactions with the system involve, primarily, the diversity of clienteles to be served and the variety of services to be provided, recognizing that:

48/ "The principles underlying human-engineered man-computer communication are only vaguely and intuitively sensed and are not yet part of a rigorous and formal tradition in computer science. An extensive review of the rapidly changing state of the art in man-computer communication is found in a survey by Ruth Davis (1966). Virtually no experimental studies of user performance are cited in her review. Barmack and Sinaiko (1966) encounter a similar absence of experimental data on user effectiveness in a comprehensive review of man-computer communications with graphic systems. Their consistent plea is for more experimental evaluation of human performance with graphic systems." (H. Sackman, "Current Methodological Research", 1968, p. 367).

49/ "... The services of a staff of 'circuit riders' who meet with faculty and students for training and instruction in com computers." (M.S. Davis, "Economics - Point of View of Designer and Operator", 1970, p. 4-1-3).

"The information needs of scientists, engineers, and practitioners vary markedly with the nature of their numerous types and combinations of responsibilities, such as design, development, teaching, basic research, administration, and marketing." (Scientific and Technical Communication - A Synopsis, 1969, p. 10).

A special challenge is poised to the information science community itself: "Individuals across the many disciplines that contribute to information science must cooperate in the development and use of common data forms and procedures, despite the requirements of their special interests. Also, effective logistics must be developed for the distribution of data to core centers and the transmission of data to core centers and the transmission of data from centers to satellites."50/

50/ H.D. Avram, "Using Computer Technology --- Frustrations Abound", 1969, p. 86.

CONCLUSIONS

Compatibility problems at the machine-machine and man-machine interfaces are indeed critical and urgent, especially in the context of teleprocessing networks, but the frequently neglected issues of man-to-man interface present the most significant, difficult, and challenging problems of all.

The challenges of man-man communications (including the new possibilities of interchange between any one machine-assisted-man with another), lie principally in the areas of; first, direct human intercommunication; secondly, in the improved utilization of recorded information, especially with respect to the scientific and technical literature; thirdly, with requirements for natural language text processing, and finally, inevitably, with the problems of knowing, of knowledge itself.

From the technological standpoint, however, we may conclude that the new technologies are literally forcing a new look at our problems of compatibility --- at the same time, these technologies offer new opportunities, and new aids, for the solution of some of the problems.

Resolution of man-communications-processor interface problems, will range from the socio-political or economic problems of the "computer utility" and "of copyrights and patents" to the actual design of improved modems.

Four current trends are to be noted. The first is that of the conspicuity of the compatibility problems as such. It was said of the COSATI microfiche standards that: "For the first time the federal government is on a standard before too many noncompatible systems get started."[51/] A second trend is toward increasing compromise.

Compromise necessarily involves both systems and society. What are the specific needs for interface message processing and for normalization and standardization in information interchange? What, on the other hand, are the real requirements for the protection of the individual, in general, from the individual, in particular? More specifically, compromise involves:

- Emphasis upon interchange
- Emphasis upon versatile "black boxes" at interfaces
- Agreement upon standardized descriptions
- Agreement upon standardized documentation requirements
- Agreement upon protocols of interface and interchange, and for overall network management, control, and evaluation.

In general, "A network must impose a series of constraints in order to operate, but it also allows for the flexibility that a rigidly structured system cannot accommodate. A network also fosters a sense of competition in which each community must ever

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51/ C.P. Yerkes, "Microfiche, A New Information Media", 1963, p. 129.

strive to re-orient itself in order to survive and progress in its changing environment. In addition, each must become sensitive to the changes in the other communities in order that it may react, re-evaluate and adapt to the new set of goals that are inevitable."52/

A third current trend is that of increasing commitment to the use of machines as aids, or even as alternatives, to man in problem-solving and decision-making and the maintenance of appropriate checks-and-balances in social, economic, and political areas (medical data interpretation and diagnosis, novelty searching in the case of patent applications, relief of the creative artist or engineer of innumerable tedious tasks of routine design, air traffic control, and the like.)

Fourth, but not least, is the continuing trend toward increasing cooperation. There remain a number of unresolved problems and difficulties. For example:

- How is greater collaboration and cooperation to be achieved?
  - By fiat?
  - By charging-policy advantages and penalties?
  - By salesmanship? (But if so, how?)
- What can we do about convertibility for the "underprivileged" or the "disadvantaged" or the "underdeveloped"?

52/ P. Vlannes, "Requirements for Information Retrieval Networks", 1964, p. 4.

Nevertheless, the solution of tractable compatibility problems in network interfacing should promote the more effective collaboration and cooperation throughout the computer science, information science, and library communities. We may conclude that "the little that has been done to this time is only the earnest of what is yet to come."53/

53/ Proceedings of the Librarians' Convention ... 1853, p. 55.

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